can be displayed.

The driving voltage required for the column driver 31 and row driver 32 in the liquid crystal driving circuit 21 described by using Fig. 5 to drive the cholesteric liquid crystal panel 1 is the lowest value of (V1+V2)/2 when V1 = V2. Thus, the breakdown voltage of the column driver 31 and the row driver 32 must be equal to or greater than (V1+V2)/2.

Although bipolar pulse voltage Vps for changing the state to the planar state and bipolar pulse voltage Vfs for changing the state to the focal conic state differ depending on inter-electrode gap thickness, for example, when the gap thickness is 5 μm, it is required that Vps = approximately 40 V, and Vfs = approximately 20 V. Accordingly, to satisfy V1+V2 > Vps, the column driver 31 and the row driver 32 each require a breakdown voltage of approximately 20 V.

It is very difficult to reduce the size and cost of driving circuits for driving the cholesteric liquid crystal.

Disclosure of Invention

The present invention has been made in view of such circumstances, and is intended to reduce a voltage value supplied as a driving voltage to each driver for driving cholesteric liquid crystal.

A display device of the present invention comprises: a display means in which, by applying voltages to row

electrodes and column electrodes, the state of cholesteric liquid crystal is changed to display information; a row driver for applying a voltage to the row electrodes; a column driver for applying a voltage to the column electrodes; a row-driver-reference-voltage switching means for selectively switching a first reference voltage (e.g., GNDr) supplied to the row driver between a first voltage having a voltage value (e.g., V1+V2) greater than the absolute value of the bipolar voltage required for setting the state of the cholesteric liquid crystal to a planar state, and a zero volts; a column-driver-reference-voltage selectively switching means for switching a second reference voltage (e.g., GNDc) supplied to the column driver between a second voltage (-V1-V2) whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage, and zero volts; and a control means for controlling the operation of the row driver and the column driver, the row-driver-reference-voltage switching means, and the column-driver-reference-voltage switching means. A driving voltage supplied to the row driver is a first bipolar driving voltage whose absolute value is a third voltage (e.g., V3). A driving voltage supplied to the column driver is a second bipolar driving voltage whose absolute value is a fourth voltage (e.g., V4). The sum of the third voltage and the fourth voltage is a voltage value greater than the

voltage value required for setting the state of the cholesteric liquid crystal to a focal conic state. When the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means to set the first reference voltage as the first voltage, the control means controls the column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and controls the row driver and the column driver so that the first reference voltage is applied to the row electrodes and the second reference voltage is applied to the column electrodes, and, in order to set a desired portion of the cholesteric liquid crystal to the focal conic state, the control means controls the row-driver-reference-voltage switching means and the column-driver-reference-voltage switching means to switch each of the first reference voltage and the second reference voltage to zero volts, and controls the row driver and the column driver to control supply of the first bipolar driving voltage and the second bipolar driving voltage to the cholesteric liquid crystal.

The row driver may be supplied with the first bipolar driving voltage, the column driver may be supplied with the second bipolar driving voltage, the first bipolar driving voltage and the second bipolar driving voltage each may be a voltage value in which the sum (e.g., V3+V4) of the absolute

values of the third voltage and the fourth voltage is approximately a half of the first voltage, and, when the control means sets the desired portion of the cholesteric liquid crystal to the focal conic state, the control means may control the row driver to sequentially apply the first bipolar driving voltage so as to scan the row electrodes, and may control the column driver to selectively apply, to the column electrodes, the second bipolar driving voltage, which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

A display method of the present invention includes: a first reference-voltage applying step of supplying zero volts as a first reference voltage (e.g., GNDr) to a row driver which applies a voltage to row electrodes and supplying the first reference voltage to the row electrodes; a second reference-voltage applying step of supplying zero volts as a second reference voltage (e.g., GNDc) to a column driver which applies a voltage to column electrodes and applying the first reference voltage to the row electrodes; a first reference-voltage control step of, in order to set the cholesteric liquid crystal to a planar state, controlling the first reference voltage applied to the row driver to perform switching from zero volts to a first voltage having a voltage value (e.g., V1+V2) greater than the absolute value of the bipolar driving voltage required

for setting the state of the cholesteric liquid crystal to the planar state; a second reference-voltage control step of, in order to set the cholesteric liquid crystal to the planar state, controlling the second reference voltage applied to the column driver to perform switching from zero volts to a second voltage (e.g., -V1-V2) whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage; a third switching step (e.g., S7 in Fig. 12) of, in order to set a desired portion of the cholesteric liquid crystal to a focal conic state, controlling the first reference voltage applied to the row driver to perform switching from the first voltage to zero volts, and controlling a second driving voltage applied to the column driver to perform switching from the second voltage to zero volts; and a display control step of controlling display of information on the display unit by, in order to set the desired portion of the cholesteric liquid crystal to the focal conic state, applying a first bipolar driving voltage so as to scan the row electrodes, and selectively applying a second bipolar driving voltage to the column electrodes, the second bipolar driving voltage having an absolute value equal to the first voltage and being reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes. A driving voltage supplied the row driver is the first bipolar driving voltage, whose absolute value

is a third voltage (e.g., V3), a driving voltage supplied to the column driver is the second bipolar driving voltage, whose absolute value is a forth voltage (e.g., V4), and the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for setting the state of the cholesteric liquid crystal to a focal conic state.

The first bipolar driving voltage and the second bipolar driving voltage each may have a voltage value in which the sum (e.g., V3+V4) of the absolute values of the third voltage and the fourth voltage is approximately a half of the first voltage.

In the display device and display method of the present invention, after the reference voltage applied to the row electrodes is controlled to perform switching from zero volts to the first voltage having a voltage value (e.g., V1+V2) greater than the absolute value of the bipolar voltage required for setting the state of cholesteric liquid crystal to the planar state, the reference voltage applied to the column electrodes is controlled to perform switching from zero volts to the second voltage (e.g., -V1-V2) whose absolute value is the first voltage and which is reverse in polarity to the first voltage, whereby the cholesteric liquid crystal is changed to be in the planar state.

A liquid crystal driving circuit of the present

invention includes: a row driver for applying a voltage to row electrodes of a liquid crystal display element; a column driver for applying a voltage to column electrodes of the liquid crystal display element; a row-driver-reference-voltage switching means for selectively switching a first reference voltage (e.g., GNDr) supplied to the row driver between a first voltage having a voltage value (e.g., V1+V2) greater than the absolute value of the bipolar driving voltage required to setting the state of the cholesteric liquid crystal to a planar state, and zero volts; a column-driver-reference-voltage switching means for selectively switching a second reference voltage (e.g., GNDc) supplied to the column driver between a second voltage (e.g., -V1-V2) whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage, and zero volts; and a control means for controlling operation of the row driver and the column driver, and the row-driver-reference-voltage switching means and the column-driver-reference-voltage switching means. A driving voltage supplied to the row driver is a first bipolar driving voltage whose absolute value is a third voltage (e.g., V3), a driving voltage supplied to the column driver is a second bipolar driving voltage whose absolute value is a fourth voltage (e.g., V4), and the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for

setting the state of the cholesteric liquid crystal to a focal conic state. When the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means to set the first reference voltage as the first voltage, the control means controls the column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and controls the row driver and the column driver so that the first reference voltage is applied to the row electrodes and the second reference voltage is applied to the column electrodes, and, in order to set a desired portion of the cholesteric liquid crystal to a focal conic state, the control means controls the row-driver-reference-voltage switching means and the column-driver-reference-voltage switching means to switch each of the first reference voltage and the second reference voltage to zero volts, and controls the row driver and the column driver to control supply to the cholesteric liquid crystal of the first bipolar driving voltage and the second bipolar driving voltage.

The row driver may be supplied with the first bipolar driving voltage, the column driver may be supplied with the second bipolar driving voltage, the first bipolar driving voltage and the second bipolar driving voltage each may be a voltage value in which the sum of the absolute values of the

third voltage and the fourth voltage is approximately a half of the first voltage, and, when the control means sets the desired portion of the cholesteric liquid crystal to the focal conic state, the control means may control the row driver to sequentially apply the first bipolar driving voltage so as to scan the row electrodes, and may control the column driver to selectively apply, to the column electrodes, the second bipolar driving voltage, which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

A liquid crystal driving method of the present invention includes: a first reference-voltage applying step of supplying zero volts as a first reference voltage (e.g., GNDr) to a row driver which applies a voltage to the row electrodes and supplying the first reference voltage to the row electrodes; a second reference-voltage applying step of supplying zero volts as a second reference voltage (e.g., GNDc) to a column driver which applies a voltage to the column electrodes and applying the first reference voltage to the row electrodes; a first reference-voltage control step of, in order to set the cholesteric liquid crystal to a planar state, controlling the first reference voltage applied to the row driver to perform switching from zero volts to a first voltage having a voltage value (e.g., V1+V2) greater than the absolute value of the bipolar

driving voltage required for setting the state of the cholesteric liquid crystal to the planar state; a second reference-voltage control step of, in order to set the cholesteric liquid crystal to the planar state, controlling the second reference voltage applied to the column driver to perform switching from zero volts to a second voltage (e.g., -V1-V2) whose absolute value is equal to the first voltage and which is reverse in polarity to the first voltage; a third switching step (e.g., S7 in Fig. 12) of, in order to set a desired portion of the cholesteric liquid crystal to a focal conic state, controlling the first reference voltage applied to the row driver to perform switching from the first voltage to zero volts, and controlling a second driving voltage applied to the column driver to perform switching from the second voltage to zero volts; and a driving-voltage-application control step of, in order to set the desired portion of the cholesteric liquid crystal to the focal conic state, controlling sequential application of a first bipolar driving voltage to the row electrodes, and controlling selective application, to the column electrodes, of a second bipolar driving voltage having a voltage value which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes, and whose absolute value is equal to the first voltage. A driving voltage supplied the row driver is the first bipolar

driving voltage, whose absolute value is a third voltage (e.g., V3), a driving voltage supplied to the column driver is the second bipolar driving voltage, whose absolute value is a forth voltage (e.g., V4), and the sum of the third voltage and the fourth voltage is a voltage value greater than the voltage value required for setting the state of the cholesteric liquid crystal to the focal conic state.

The first bipolar driving voltage and the second bipolar driving voltage each may be a voltage value in which the sum (e.g., V3+V4) of the absolute values of the third voltage and the fourth voltage is approximately a half of the first voltage.

In the display device and display method of the present invention, after the reference voltage applied to the row electrodes is controlled to perform switching from zero volts to the first voltage having a voltage value (e.g., V1+V2) greater than the absolute value of the bipolar voltage required for setting the state of cholesteric liquid crystal to the planar state, the reference voltage applied to the column electrodes is controlled to perform switching from zero volts to the second voltage (e.g., -V1-V2) whose absolute value is the first voltage and which is reverse in polarity to the first voltage, whereby the cholesteric liquid crystal is changed to be in the planar state.

Brief Description of the Drawings

Fig. 1 is an illustration of a cholesteric liquid crystal panel.

Fig. 2 is an illustration of the cholesteric liquid crystal panel.

Fig. 3 is a graph illustrating states of cholesteric

case of the related art, each driving voltage of the column driver 52 and the row driver 53 can be reduced to approximately a half.

As described above, in the liquid crystal display device including the liquid crystal driving circuit 41 to which the present invention is applied, by resetting display while suppressing the voltages supplied as driving voltages to the drivers, the color of arbitrary pixels can be inverted from a specified wavelength color to black.

In addition, the driving voltages of drivers (here, the column driver 52 and the row driver 53) of the liquid crystal driving circuit for driving the cholesteric liquid crystal panel 1 decrease, whereby elements whose package is small can be selected for the drivers. Thus, liquid crystal display device size can be reduced.

Furthermore, based on a reduction in the driving voltage of the drivers in the liquid crystal driving circuit for driving the cholesteric liquid crystal panel 1, one in which electric double layer capacitors that are connected in series to each other, etc., can be used as a battery for supplying power to the drivers (for example, by further stepping up the voltage by using one in which electric double layer capacitors having capacity of 2.5 V are connected in series to one another, the required voltage value can be sufficiently supplied). Thus, liquid crystal

CLAIMS

1. (Amended) A display device comprising:

display means in which, by applying voltages to row electrodes and column electrodes, the state of cholesteric liquid crystal is changed to display information;

a row driver for applying a voltage to the row electrodes;

a column driver for applying a voltage to the column electrodes;

row-driver-reference-voltage switching means for switching a first reference voltage supplied to the row driver between a first voltage having a voltage value obtained by adding values V1 and V2, and zero volts;

column-driver-reference-voltage switching means for switching a second reference voltage supplied to the column driver between a second voltage which is reverse in polarity to the first voltage, and zero volts; and

control means for controlling the operation of the row driver and the column driver, the row-driver-reference-voltage switching means, and the column-driver-reference-voltage switching means,

wherein, when the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means to set the first reference voltage as the first voltage, the control means

controls the column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and the control means controls the row driver and the column driver so as not to apply driving voltages to the row electrodes and the column electrodes.

2. (Amended) The display device according to claim 1, wherein:

the row driver is supplied with a first bipolar driving voltage having a voltage value whose absolute value is equal to value V3;

the column driver is supplied with a second bipolar driving voltage having a voltage value whose absolute value is equal to value V4;

the first bipolar driving voltage and the second bipolar driving voltage each have a voltage value in which the sum of values V3 and V4 is approximately a half of the sum of values V1 and V2; and

when the control means sets the cholesteric liquid crystal to a focal conic state, the control means controls the row driver to sequentially apply the first bipolar driving voltage so as to scan the row electrodes, and controls the column driver to selectively apply, to the row electrodes, the second bipolar driving voltage, which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

3. (Cancelled)

4. (Cancelled)

5. (Amended) A display method for a display device comprising a display unit which displays information with cholesteric liquid crystal by applying voltages to row electrodes and column electrodes, the display method including:

a first reference-voltage applying step of applying a first reference voltage of zero volts to the row electrodes;

a second reference-voltage applying step of applying the first reference voltage of zero volts to the column electrodes;

a first reference-voltage control step of controlling a reference voltage applied to the row electrodes to perform switching from the first reference voltage of zero volts to a second reference voltage having a voltage value obtained by adding values V1 and V2;

a second reference-voltage control step of controlling a reference voltage applied to the column electrodes to perform switching the first reference voltage of zero volts to a third reference voltage which is reverse in polarity to the second reference voltage; and

a display control step of controlling the display of the information on the display unit by sequentially applying a first bipolar driving voltage so as to scan the column

electrodes, the first bipolar driving voltage having a voltage value whose absolute value is equal to value V3, and selectively applying a second bipolar driving voltage to the column electrodes, the second bipolar driving voltage having a voltage value whose absolute value is equal to value V4 and being reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

6. (Amended) A liquid crystal driving circuit for driving liquid crystal display elements including cholesteric liquid crystal, the liquid crystal driving circuit comprising:

a row driver for applying a voltage to row electrodes of the liquid crystal display elements;

a column driver for applying a voltage to column electrodes of the liquid crystal display elements;

row-driver-reference-voltage switching means for selectively switching a first reference voltage supplied to the row driver between a first voltage having a voltage value obtained by adding values V1 and V2, and zero volts;

column-driver-reference-voltage switching means for selectively switching a second reference voltage supplied to the column driver between a second voltage being reverse in polarity to the first voltage, and zero volts; and

control means for controlling the operation of the row driver and the column driver, the row-driver-reference-voltage switching means, and the column-driver-reference-

voltage switching means,

wherein, when the control means sets the cholesteric liquid crystal to a planar state, after controlling the row-driver-reference-voltage switching means to set the first reference voltage as the first voltage, the control means controls the column-driver-reference-voltage switching means to set the second reference voltage as the second voltage, and the control means controls the row driver and the column driver so as not to apply driving voltages to the row electrodes and the column electrodes.

7. (Amended) A liquid crystal driving method for a liquid crystal driving circuit which drives liquid crystal display elements including cholesteric liquid crystal by applying voltages to row electrodes and column electrodes, the liquid crystal driving method including:

a first reference-voltage applying step of applying a first reference voltage of zero volts to the row electrodes;

a second reference-voltage applying step of applying the first reference voltage of zero volts to the column electrodes;

a first reference-voltage control step of controlling a reference voltage supplied to the row electrodes to perform switching from the first reference voltage of zero volts to a second reference voltage having a voltage value obtained by adding values V1 and V2;

a second reference-voltage control step of controlling a reference voltage supplied to the column electrodes to perform switching from the first reference voltage of zero volts to a third reference voltage being reverse in polarity to the second reference voltage;

a driving-voltage-application control step of controlling sequential scanning application of a first bipolar driving voltage having a voltage value whose absolute value is equal to value V3, and controlling selective application, to the column electrodes, of a second bipolar driving voltage having a voltage value whose absolute value is equal to value V4 and being reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

8. (Added) The display method according to claim 5, wherein the first bipolar driving voltage and the second bipolar driving voltage each have a voltage value in which the sum of values V3 and V4 is approximately a half of the sum of values V1 and V2.

9. (Added) The display method according to claim 6, wherein:

the row driver is supplied with a first bipolar driving voltage having a voltage value whose absolute value is equal to value V3;

the column driver is supplied with a second bipolar

driving voltage having a voltage value whose absolute value is equal to value V4;

the first bipolar driving voltage and the second bipolar driving voltage each have a voltage value in which the sum of values V3 and V4 is approximately a half of the sum of values V1 and V2; and

when the control means sets the cholesteric liquid crystal to a focal conic state, the control means controls the row driver to sequentially apply the first bipolar driving voltage so as to scan the row electrodes, and controls the column driver to selectively apply, to the column electrodes, the second bipolar driving voltage, which is reverse in polarity to the first bipolar driving voltage applied so as to scan the row electrodes.

10. (Added) The liquid crystal driving method according to claim 7, wherein the first bipolar driving voltage and the second bipolar driving voltage each have a voltage value in which the sum of values V3 and V4 is approximately a half of the sum of values V1 and V2.